COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

February, 1948

Before the evening peak

David W. Corson, A. Devaney, Inc., N. Y.

Keystone Steel and Wire Company Adds to Boiler Capacity ▶

Modern Boiler Design Increases Availability ▶

A Sub-Saturation Reheat Cycle ▶

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME NINETEEN NUMBER EIGHT

CONTENTS

FOR FEBRUARY 1948

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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EDITORIAL

St. Lawrence Power Up for Congressional Action

The proposed St. Lawrence Seaway and Power Development has kicked around for many years, coming up periodically before Congress and being laid over, first for one reason and then another. It will be recalled that agitation by its proponents became very strong in 1941, at which time action was deferred on the grounds that it could not be completed in time to aid the war effort and that it would utilize both labor and materials sorely needed in war production. Now the Senate, after a favorable report by its Foreign Relations Committee and indorsement by the President, has again taken up consideration of the matter.

The project involves two distinct but related phases—construction of a seaway approach to the Great Lakes and development of a large block of hydroelectric power amounting to well over a million kilowatts of firm capacity. The former is being urged by shipping and other interests on the Lakes and is opposed by such bodies as the New York Port Authority and the American Railroad Association, as well as by the Mayor of New York. The power development is being pushed by various public power groups, backed by a segment of political opinion, but is opposed by the coal industry and certain factions of organized labor. So far the power industry does not appear to have taken an active, or at least vocal part in the controversy, probably lest its motives be misunderstood.

Cost of the project is estimated to run well over a billion dollars, and probably much more if the waterway is to be made deep enough to accommodate large vessels, although navigation would be open only for about seven months of the year.

The national defense angle stressed by many of the proponents, because of its popular appeal, has been seriously questioned by some military experts who consider it a liability rather than an asset.

As for the power part of the project, it is true that post-war demand, for the country as a whole, has climbed at an unprecedented rate and is expected to continue unabated; also that a power shortage was barely averted last fall. These facts are being cited by those who would push the project. However, the rate of installing new steam generating equipment has not only caught up with but now actually exceeds that of load increase, and the very large capacity now under construction and on order insures an adequate margin of reserve for several years to come, which condition it is assumed will be maintained by continuing new construction. Furthermore, it is well to remember that steam capacity can be provided at lower initial cost than hydro. This is an economic angle which deserves fullest consideration.

In view of the foregoing, one is led to question the wisdom of pushing such a project at a time when all taxpayers are being committed to vast expenditures over a period of years for European relief, together with a heavy burden of war-incurred debt, particularly when only one section of the country would benefit.

It just doesn't make sense.

Colloidal Fuel

The present fuel oil situation has led to numerous suggestions for its alleviation pending commercial development of synthetic processes to supplement the natural supply. One such suggestion is that we again look into the possibilities of employing colloidal fuel—a mixture of oil and finely pulverized bituminous coal.

Colloidal fuel, of course, is not new. Experiments with it in the marine field were conducted during the first world war. These were followed by extensive investigations and some applications abroad, particularly in England; but one of the difficulties was finding a stabilizer that would prevent particles of coal from settling when left standing for a considerable time.

Subsequently the U. S. Bureau of Mines undertook both laboratory and field tests of coal-in-oil mixtures, the results of which were published in an A.S.M.E. paper in 1943. These studies showed that a reasonably stable suspension could be obtained with 40 per cent coal, by weight, ground to 98 or 99 per cent through 230 mesh, and heavy fuel oil. Fineness of grinding and viscosity, as well as specific gravity, of the oil were most important; and careful control of storage and handling temperatures was necessary. Steam atomizing burners were employed. Ash or slag deposits presented no serious difficulty, nor were there troublesome accumulations in the pipe lines; although the heaters did give some trouble. Therefore, it was concluded that use of such mixtures had the best chance of success in large plants having better qualified operating personnel and accessible equipment.

It has been further suggested that a stable suspension for colloidal fuel might be brought about through supersonic methods such as are now being employed in connection with certain other mixtures and processes.

In our present age of progress and development many previously tried ideas have been revived and put to use. Colloidal coal may or may not prove to be in this category. Who can tell?

Keystone Steel & Wire Co. Increase in Boiler Capacity

By WALTER GAUMER*
and M. O. FUNK†

Following installation of a power plant in 1940, expansion in load increased to the extent that it became necessary to add a new 150,000-lb per hr spreader-stoker-fired steam generating unit, which went into service in July 1947; and to plan for 10,000 kw additional turbine-generator capacity. Detailed performance figures of the new unit are given.

A SURVEY to determine the initial size of power plant to supply heating and process steam and power requirements for the Keystone Steel & Wire Co. covered the period from 1935 to 1939. Previous to this power had been purchased and steam was supplied by several small boilers. Peak load from this survey was estimated at approximately 8000 kw and 140,000 lb of steam per hour at 250 psi and 600 F.

The power plant, which was built to take care of these requirements, plus provision for one spare boiler and a spare 7500-kw turbine-generator was first put into operation on May 31, 1940. All the equipment was second-hand except the 17 panel switchboard and the boiler feed pumps. These boilers had been built in 1916, the stokers in 1927 and the turbine in 1918. Peak load with this equipment developed to 275,000 lb of steam per hour and 15,000 kwhr.

Soon after the power plant went into operation increased demand for the company's products necessitated using the spare equipment in normal operation. Production schedules called for 24-hr operation, 7 days each week. "In Service" time on the three boilers and four turbines amounted to 95 per cent. The 5 per cent outage time, and this only when some mill might be down for repairs, did not permit establishing a regular inspection and maintenance schedule. Therefore, in 1944 the management decided to increase the steam generating capacity and also to plan for additional future turbine-generator capacity.

The steel and wire mills are located in South Bartonville, Ill., and are near the Peoria and Fulton County coal mines. In normal times advantage can be taken of the off-season coal production from these mines. This coal

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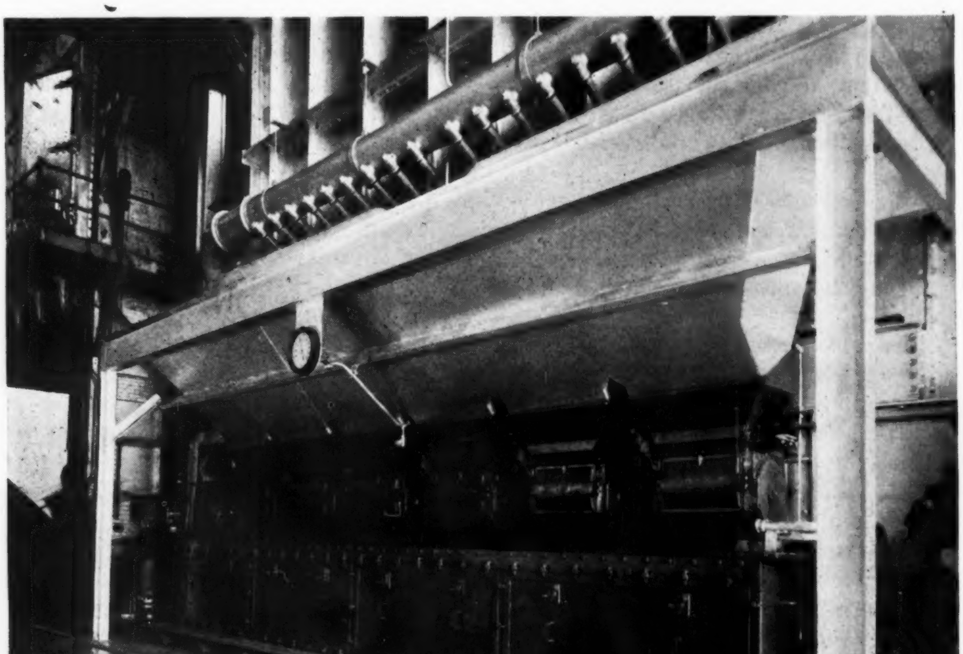

Fig. 1—Front of new 150,000-lb per hr steam generating unit

ranges from bug dust and machine cuttings to $1^{1}/_{4}$-in. washed screenings, analyzing from 8 to 18 per cent ash, 25 to 37 per cent volatile matter, 35 to 48 per cent fixed carbon, and 8889 to 10,861 Btu per lb, all on an "as received" basis. This meant that the fuel burning equipment must be able to use a wide range of fuel, and a continuous-ash-discharge spreader stoker was chosen.

Size of the new boiler was determined so as to release one boiler in the winter months and two boilers during the summer. Maintenance and inspection on the new unit would be done in the late fall months when the older boilers could take the load, and any one of the older boilers could be taken down at any other time during the year. The physical dimensions of the new boiler would have to be kept within limits as to length but not as to width and height.

As the operating crew on each shift consists of four men: an engineer, fireman, oiler and coal and ash man—and as the maintenance crew was small, reliability, simplified operation and maintenance of the fuel burning equipment while in operation were important considerations.

New Steam Conditions

The management decided to employ a higher steam pressure and temperature of 450 psi and 750 F, for the new boiler, and the proposed 10,000-kw turbine is to be an extraction machine capable of supplying 75,000 lb of bled steam per hour at 30 psi for heating and process work.

Proposals were requested on the foregoing basis, and when received were thoroughly studied by the management and the engineering department. At the time proposals were requested only one company was in position to assume unit responsibility for a continuous-discharge spreader stoker and boiler. The design submitted by this company left only the building, piping and electrical planning to be handled by the purchaser's engineering department. The boiler equipment and auxiliaries which were chosen are as follows:

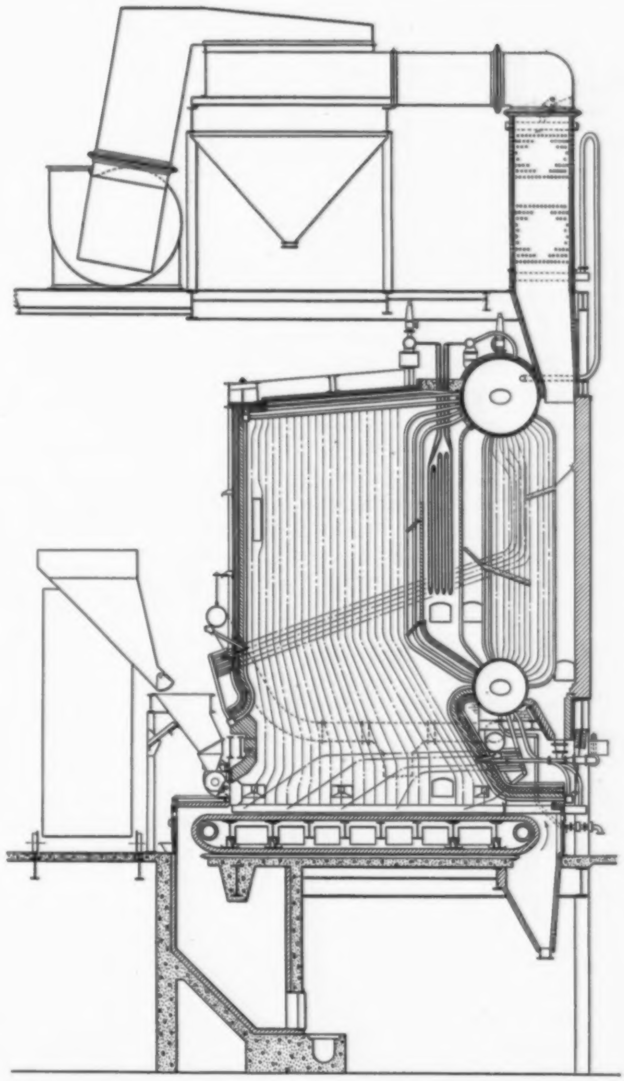

Fig. 3—Cross-section of steam generating unit

Boiler: CEC, 150,000 lb of steam per hour, 500 psi design pressure 750 F total steam temperature and of the two-drum type. The boiler heating service was 12,050 sq ft and that of the water walls 2275 sq ft.

Superheater: "Elesco" of 2780 sq ft heating service.

Economizer: "Elesco" with 6120 sq ft heating service.

Stoker: CEC continuous-discharge spreader type, 22 ft wide, 20 ft long, with six 24-in. feeder units.

Fans: Forced-draft fan, Green Fuel Economizer Co., 59,500 cfm at 3.4-in. wg driven by 60-hp motor. Induced-draft fan, Green Fuel Economizer Co., 134,000 cfm, at 12.1-in. wg driven by 450-hp motor. Cinder-recovery fan, Buffalo Forge Co., 400 cfm at 14-in. wg. Overfire air fan, Clarage Fan Co., 5200 cfm at 35-in. wg, driven by 50-hp motor.

Soot blowers: Diamond Power Specialty Corp., steam-operated.

Dust collector: Prat-Daniel.

Ash disposal: Allen-Sherman-Hoff system.

Boiler controls: Republic Flow-Meter Company.

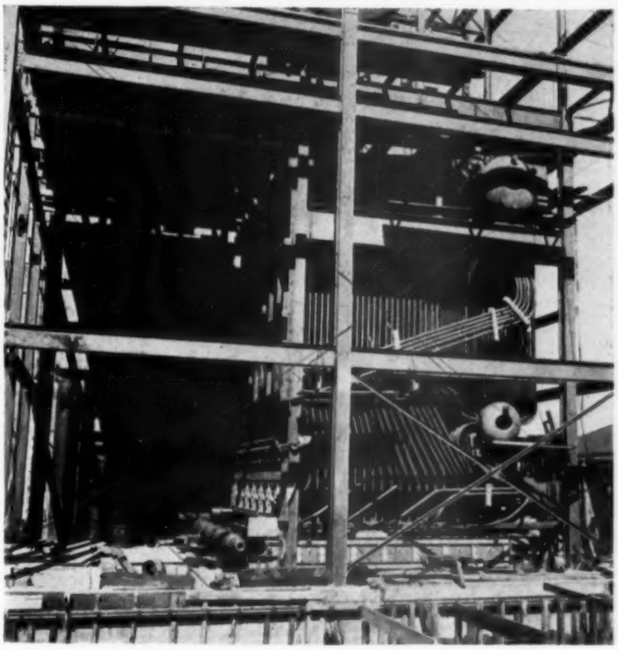

Fig. 2—Construction view of unit before applying casing

Predicted performance for this equipment was as follows, based on coal analysis "as received" of 9959 Btu per lb, 13.98 per cent moisture, 31.75 per cent volatile, 40.22 per cent fixed carbon and 14.05 per cent ash:

Evaporation, lb per hr	150,000
Overall efficiency, per cent	80.1
Total steam temperature, deg F*	750
Pressure drop through superheater, lb	14*
Total fuel as fired, lb per hr	22,000
Draft loss through boiler and superheater, in. water	2.95
Boiler exit gas temperature, deg F	685
CO_2 leaving boiler, per cent	13.5
Combustion rate, lb/sq ft/hr	50
Gas through economizer, lb/hr	238,000
Water through economizer, lb/hr	150,000
Temperature of gas entering economizer, deg F	685
Temperature of gas leaving economizer, deg F	450
Temperature of feedwater, deg F	250
Temperature of water leaving economizer, deg F	341
Pressure loss in economizer, lb/sq in	11.5
Draft loss through economizer, in. of water	2.25

* Due to subsequently leaving out approximately one thir of the superheater tubes to maintain the steam temperature at 640 F., the pressure drop through the superheater became about 30 lb.

Excavation for the boiler plant addition was started in August 1945 and later suspended until June 1946, when work was resumed. The boiler was ready for service in December 1946, but delivery on some valves held up initial operation until July 1947. Boiler load was held between 50,000 and 75,000 lb of steam per hour for several weeks before bringing it up to the design capacity of 150,000 lb per hr. After two months' operation the boiler was taken out of service in order to make some minor changes. It was back in service on September 29, 1947, and since then to date has been out only 90 hr including the Armistice Day holiday and during the Christmas holiday. The load has averaged between 135,000 and 150,000 lb per hr except on some Sundays when lower steam demand required a drop to 25,000 or 30,000 lb per hr.

Since coal for the old traveling-grate stokers and the new continuous-discharge spreader is handled through the same system, the feeder units of the latter are required to handle very wet coal, as it is tempered for the old stokers; but feeder units have handled this wet coal most satisfactorily. Grate carrier bars and keys have been removed and replaced and individual feeder units have been inspected while the boiler has been carrying full load.

Cinders from the boiler hopper are re-injected and burned in the furnace and overfire air is injected through the rear arch. There is also provision for air injection through the front arch, but this is used only rarely, when burning very dry coal.

Hoppers of the Prat-Daniel dust collectors are cleaned once every 24 hr and fly ash has been no problem. Smoke emission from the stack is barely discernible when the boiler is operating between 25,000 to 150,000 lb of steam per hour. Combustible matter in the fly ash collected in the dust collectors has averaged 31 per cent and that in the ash leaving the grate has been less than 2 per cent.

The following are average performance data and calculations for a 16-hr period on November 29, 1947:

Attained Performance

Feedwater to economizer, lb per hr	166,200
Steam evaporated, lb per hr	149,375
Continuous blowdown, lb per hr	16,825
Steam pressure, psia	465
Steam temperature, deg F	645
Feedwater temperature, deg F	252
Heat absorbed by steam, 10^6 Btu/hr	165.5
Heat absorbed, by blowdown, 10^6 Btu/hr	3.7
Heat absorbed, total 10^6 Btu/hr	169.2
Coal burned, lb per hr	20,600
Heat in coal, Btu/lb	9900
Heat released, total Btu/hr	204.0
Efficiency, per cent	83

These average data were collected under normal operating procedure and are representative of continuous performance of the unit. It will be noted that the performance in continuous service exceeds that predicted in the original proposals for the installation.

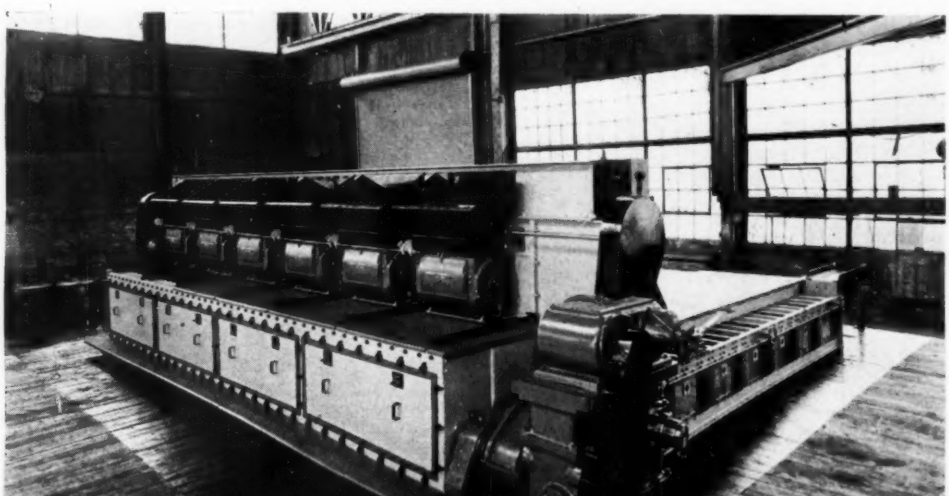

Fig. 4—Continuous-discharge spreader stoker assembled in shop before shipment

Modern Boiler Design Increases Availability*

By A. R. MUMFORD
Development Engineer,
Combustion Engineering Co.

One of the principal factors influencing availability is the formation of slag on heating surfaces. This is examined in some detail, and control of its deposition through use of cooling screens, burner position and relation of flame envelope to water-cooled furnace area is discussed, as is also use of shielding for uncooled parts when designing for supplementary fuels. To meet load variations at high pressures, dependence must be placed on ability to change heat input rapidly rather than on the flywheel effect of a large mass of boiling water. Typical designs of recent units for the steel industry are shown.

As THE art of boiler design progresses those elements which restrict output by limiting the rate of steam generation or by compelling outages are gradually altered to reduce or eliminate the particular restriction. When the principal cause of outage is eliminated the next most important cause becomes the object of concentrated study. It is not inferred that only one cause at a time is the subject of concentrated study but the most important naturally receives the most attention. An improvement in design must await the establishment of a performance record under commercial operating conditions before becoming widely accepted and before that it must appeal to a purchaser sufficiently to warrant trial. For these reasons improvements are usually not accomplished within a short time. During these periods new problems are likely to arise, frequently by changes in operating practices and the economic availability of other fuels, as well as changes in the nature of the load curve.

The designers of steam generating units meet these problems not only with a background of experience with other units in the same industry but with the broader experience based on all other industries. Design is evolving continuously, therefore, not only to meet changing economic conditions but to increase the availability and earning power of the equipment.

Availability is commonly defined as the ratio between the number of hours a piece of equipment is producing or is capable of producing and the total number of hours in the period, usually a year.

Factors Influencing Availability

Some of the more important factors which influence availability will be discussed. Many have been reduced in importance or eliminated by design changes, but others are so closely connected with operating procedures that changes in design alone will probably never completely eliminate them.

* Condensed from a paper before the Association of Iron and Steel Engineers at Pittsburgh, Pa., September 23, 1947.

Slag

Slag resulting from the unburnable mineral matter associated with coal, in older designs, interfered seriously with continuous production of steam at rated capacity. This material, heated to its softening or melting temperature, adheres to and builds up on the heating surfaces with which it comes in contact, gradually closes the free area available for passage of the gas. This increases the resistance and finally forces operation at reduced capacity until the obstructions are removed. Also, when this material deposits on the water-cooled walls of the furnace it insulates them and lowers the furnace heat absorption. Such a decrease in furnace wall absorption lessens the cooling action on the gas and causes it to enter the boiler section at a higher temperature, possibly high enough to maintain the slag in a sticky condition or to increase the difficulties of superheat control. Slag is of such importance to availability that factors affecting its control will later be discussed more fully.

Exposure of Uncooled Equipment

The introduction of fuel and air into a furnace cavity requires openings in the water-cooled walls. Radiant heat from the flame will impinge on any equipment exposed by these holes and cause growth or warping which eventually necessitates an outage for maintenance. The exposed equipment, if burners, is normally cooled by the flow of unignited fuel and air; or, if a stoker, it is protected by a layer of fuel and ash as a supplement to the cooling air. If, however, the load requirements are such that some of the fuel-burning equipment is not needed part of the time, then the cooling effect is absent and damage may result. The designer endeavors to

shield such equipment from radiant heat during its out-of-service period by interposing as much refractory or water-cooled shielding as possible between it and the flame without interfering with operation. In earlier designs flame temperatures were not as high as is common today and damage not so potentially immediate or extensive. Furthermore, there was less likelihood of such firing equipment being out of service because multi-fuel installations were not common. A steam generating unit in the steel industry is now seldom designed for the use of only one fuel. Usually provision is made for separate or simultaneous burning of two to four fuels. When the primary fuel is in plentiful supply the secondary fuel, or fuels, are cut off and at this time the hazard of damage to uncooled or unshielded equipment exists. Burners have been cracked or warped and stokers have been warped sufficiently to render them inoperative. The designer has become increasingly aware of this hazard to availability and now designs such installations with a maximum of refractory or water-cooled shielding to afford protection.

Water Conditioning

Not much more than twenty years ago water treatment consisted, generally, of the addition of so many buckets of soda ash to the water supplied to the boilers. Pressures were low and boiler turbining a routine operation. As pressures rose so did saturation temperatures and so did rates of heat transfer through tube walls. Experience quickly proved that "so many buckets of soda ash" were no longer adequate to protect the pressure parts and water conditioning suddenly matured as a necessary technical adjunct to steam plant operation. In the steel industry the chemical knowledge and ability are present in one phase of the operations so that the inclusion of this phase of steam production is an extension rather than a new division.

In a report on "Studies of Heat Transmission through Boiler Tubing at Pressures from 500 to 3300 Pounds" by W. F. Davidson and others[1] data were presented showing that the difference in temperature between the outside surface of a tube receiving heat and the saturation temperature of the boiling water within the tube was proportional to the rate of heat transfer. The data showed further that, at the same rate of heat transfer the difference in temperature was proportional to the wall thickness of the tube. These data are shown in Fig. 1 which is taken from that report. Although there is some scatter in the points it is obvious that a straight line is representative of the data. The significant facts apparent from this chart are as follows:

1. Δt is directly proportional to the rate of heat transfer for each line; thus Δt doubles when Q doubles.
2. The bottom line represents the data for a tube with a $^1/_8$-in. wall; the middle line a tube with a $^1/_4$-in. wall; and the upper line a tube with a $^1/_2$-in. wall. With this in mind it is at once apparent that Δt is directly proportional to the wall thickness of the tube at constant heat rate.
3. The lines have all been drawn so as to pass through the origin at zero. Although this is theoretically incorrect because of the existence of a slight temperature drop through the internal water film it is evident that the resistance of such a film must be negligible compared to the resistance of the metal wall of the tube. If the drop through the film constituted a substantial part of the total drop then it would be difficult to draw lines through the data. This serves to emphasize the importance of the wall thickness.
4. Each point for each line represents a different test with an indicated range of Q from 0 to 200,000 Btu per hr per sq ft or a wider range than has been reported in any commercial steam generators.
5. The internal pressure varied for the lower and upper curves between 500 and 3300 psia and for the middle curve from 1500 to 3200 psia. We can conclude, therefore, that Δt is independent of the internal pressure and that the tube surface temperature can be expected to be the sum of the saturation temperature and Δt at any rate of heat transfer. This is particularly important in designs calling for heavy walled tubes exposed to high rates of heat transfer and at high internal pressure. The wall thickness is normally proportional to the diameter so the larger the tube the thicker the wall. Thus, a 4-in. tube for operation at 2600 psia would have a $^1/_2$-in. wall; the saturation temperature would be 674 F and at 160,000 Btu per hr per sq ft, Δt would be 208 F. The surface temperature of the tube would be 882 F or approaching the temperature limit of the outside ligaments for boiler steel and introducing a hazard. If the tube diameter were reduced to 2 in. the surface temperature would drop to 778 F and a 1-in. tube could be expected to have a surface temperature of 726 F, all at the same heat transfer rates and internal pressure.
6. Another feature of these curves is that the mixture of steam and water within the tube varied in quality over wide limits for each line. Actually, the final quality at the discharge from these tubes was varied from 7 per cent to 100 per cent steam by weight and no effect on Δt was observed except in the superheat region. Thus, with sufficient mass flow of a mixture of water and steam

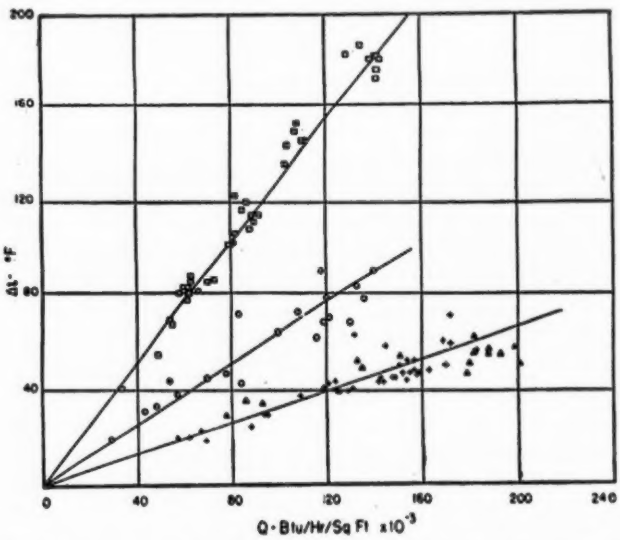

Fig. 1—Difference between tube surface and saturation temperature (Δt) versus rate of heat transmission

[1] "Studies of Heat Transmission through Boiler Tubing at Pressures from 500 to 3300 Pounds," by W. F. Davidson, P. H. Hardie, C. G. R. Humphreys, A. A. Markson, A. R. Mumford and T. Ravese, *Transactions* A.S.M.E., 1943, pp. 553–591.

through a tube, the proportions of steam and water do not affect the surface temperature of the tube.

The tests represented by Fig. 1 were all made with good but not perfect water and completed before noticeable deposits were formed on the internal surfaces. Obviously, if scale had been present Δt would have been increased by the temperature drop through the scale. Because of the high resistance of even a thin layer of scale to the passage of heat, the surface and average wall temperatures of even thin-walled tubes may become dangerously elevated. Therefore, it is obvious that water conditioning is of the utmost importance to availability. The designer can offer little help in this matter but must leave it to the operator to utilize the best available chemical knowledge to obtain and maintain scale- or deposit-free conditions on the internal surfaces.

Scale not only introduces a resistance to the flow of heat, thus raising the temperature of the tube wall, but it also provides a stagnant pocket next to the inner surface of the tube in which chemicals can concentrate and attack the hot metal. The products of the attack are usually held *in situ* by the scale and the condition is aggravated.

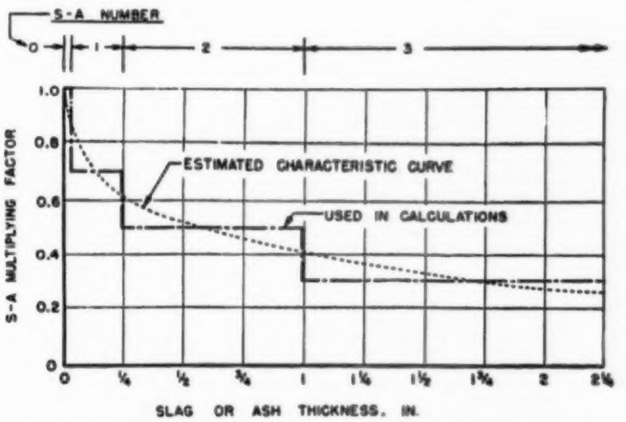

Fig. 2—Slag-ash factor for various slag thicknesses

The designer has the problem of preventing the discharge of moisture with the steam from the drum. Such moisture carries with it part of the chemical in the boiler water and on drying out in the superheater the chemical probably continues as a dry powder to the turbine where some of it deposits. Although the amount in the steam may be only 0.5 ppm the accumulation from millions of pounds of steam affects the turbine performance. This problem has become increasingly difficult with increasing operating pressures and capacities and although the separating efficiencies are now in excess of 99.9 per cent the operators request better efficiencies to improve the availability of the steam turbine-boiler combination. The principal difficulty is the discovery of a common denominator which will permit the correlation of the data from different conditions so that the fundamental factors will become more clearly evident.

To summarize, although water conditioning is an operating responsibility its effect on availability is so great that the designer cannot avoid interest. If the water conditioning is inadequate, burn-outs or internal corrosion will cause shutdowns and reduce availability. If the water conditioning permits the formation of scale, the designer's computations of the heat absorption intensities will no longer be valid and the balance between the work to be done in different parts of the unit will be upset. The influence of water conditioning on the steam purity is only partly understood and the designer, although quite successful, now is striving for further improvement.

Load Variations

Availability under fairly constant demand for steam can be built into a unit more readily than it can under conditions of a widely fluctuating demand. Temperatures, stresses and wear on moving parts are predictable with fair accuracy under constant demand conditions; but where the demand fluctuates widely the temperatures vary, the stresses change and the sudden application of load changes to moving parts changes their normal rate of wear.

Historically, the steel industry has utilized the flywheel effect of large volumes of boiling water in the pressure vessel which, when the demand suddenly increased, would convert some of its stored heat into steam as the pressure fell and thus afford the operators time to increase the heat input. At low pressures this flywheel effect is undoubtedly helpful but as the design pressures rise the available heat decreases and above 1500 psia the *volume* of boiler water required to produce one pound of steam rises very rapidly. On the assumption that a drop in pressure of 100 psi is permissible on the application of a sudden demand, the following table shows the volume of water required to produce one pound of steam.

TABLE 1

Operating Pressure, Psia	Dropped to Psia	Lb Steam Flashed per Ft³ Liquid, Lb	Ft³ Liquid Required for 1 Lb Steam Ft³
2000	1900	0.0104	96.5
1800	1700	0.05	20.0
1500	1400	0.174	5.75
1250	1150	0.322	3.11
1000	900	0.523	1.91
800	700	0.635	1.57
500	400	1.10	0.91
350	250	1.515	0.66
250	150	2.18	0.46

Obviously, if operating pressures increase to 2000 psia, over 200 times as much water would have to be present in the unit to have the same flywheel effect as an equal pressure drop at an operating pressure of 250 psia. A unit containing enough water to do this job would be slow to come on the line not only because of the mass to be heated but because temperature stresses in drums would develop with too rapid heating.

The steam generator designer, with the cooperation of control manufacturers and designers, is more hopeful that by maintaining the heated mass at a reasonable value and arranging to increase the rapidity of response to demand he will be able to increase the heat input rapidly enough to offset the lost flywheel effect of flashing as operating pressures rise. Any success in keeping the quantity of the heated mass to a low value will reduce the stresses caused by rapid changes of temperature and have a favorable effect on availability. The situation with respect to moving parts involves less heavy equipment and although wear will always be greater with

fluctuating demand its effect on availability will probably be minimized.

In units utilizing two or more fuels controls are now in operation which change the heat input rapidly not only as necessary to meet fluctuating demands but also to meet fluctuating supply of the primary fuel. It is not, therefore, too optimistic to say that rising operating pressures will change the manner of meeting fluctuating loads without introducing obstacles of major importance. One of the units to be described later is designed for 900 psig at the superheater outlet and 900 F total temperature, showing that high-pressure steam generators are becoming more common in the steel industry.

Steam Temperature

As steam pressures rise, steam temperatures also rise in order that the economies of power generation may be realized. At the higher temperatures the proportion of the heat input utilized for superheat increases and the importance of the superheater is enhanced. Although steel mills may not look forward to part load operation in the near future the usual design requirement is that the superheat reach the desired temperature at some partial load and remain essentially constant up to maximum load. Maintenance of desired superheat temperature at any load requires the heat-absorbing surfaces of the furnace and the boiler screen to be maintained free of insulating deposits in order that the heat delivered to the superheater be not excessive. If the design does not take care of furnace absorption adequately the availability of the unit will be affected. This feature will be discussed more fully in the detailed discussion of slag deposits.

Where two or more fuels are utilized the designer must not only maintain the superheat temperature over a range of loads with the primary fuel, but must also arrange the equipment so that temperature fluctuations are minimized when the secondary or other fuels are used. For steel plants the primary fuel is always blast-furnace gas and the products of combustion are most voluminous with this fuel. The large volume occupied by the products of combustion is accompanied by high rates of mass flow, and this causes the convective heat transfer rates to be higher than for the supplementary fuels. By arranging the firing position of some of the supplementary fuels so that the radiation component of heat transfer to the superheater is higher, and so that the amount of furnace cooling surface passed over by the combustion products is somewhat less, the effect of the reduced convective component is offset. Coke breeze, however, is fired on stokers at the bottom of the furnace and cannot be positioned to compensate for the decreased volume of combustion products, so some variation in steam temperature may be expected with this as a secondary fuel. If the temperature variations are not too great the economy of power generation alone is affected but, particularly at high steam temperatures, wide variations may affect the turbine because of temperature stresses. The designer's ability to locate the point of supplementary fuel firing and actually to change the direction of firing by utilizing tilting burners, as with pulverized coal, has minimized the steam temperature changes to be expected from fuels of such different characteristics.

Factors Affecting Slag

The steel industry has recognized the adverse effect of blast-furnace gas dusts, containing about 50 per cent iron and some lime, on solid fuel ashes by removing that dust so that as little as 0.01 gr per cu ft remains. However, even this small amount has been blamed for increased adherence of slag in furnaces in which solid fuel is burned simultaneously with blast-furnace gas. It is evident that a fluxing action takes place and the designer must so design the furnace that the fluxing action of the dust and the resulting insulation of the cooling surfaces is minimized in furnaces designed for the simultaneous burning of solid fuels and blast-furnace gas. The problem can be expected to be somewhat more difficult as blast-furnace gas becomes dirtier and the boiler furnaces must become more moderate in absorption rates to compensate. A balance will eventually be indicated which utilizes a furnace and a dust-cleaning procedure which combined have the highest economic efficiency.

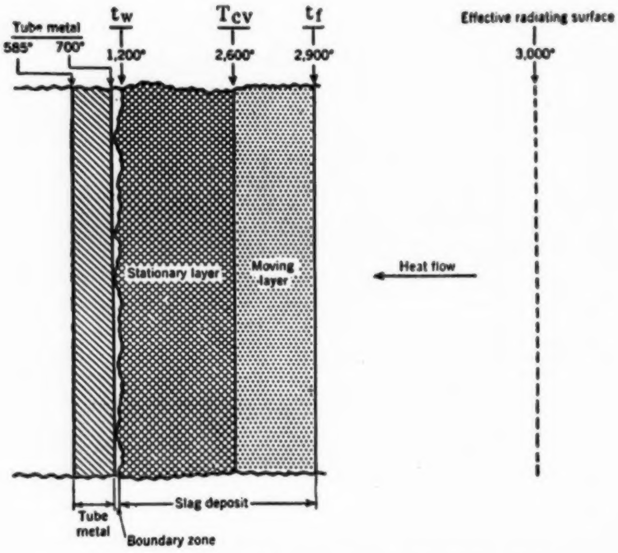

Fig. 3—Temperature distribution in slag deposit

In the absence of information as to the detailed changes in temperature and composition affecting the slag particle we can assume a series of changes to fit the overall conditions. The ash particle in the flame if solid initially will be liquefied by the addition of Fe and CaO from the blast-furnace gas dust. As it approaches the cooling surface of the walls or boiler convection surface it will be cooled perhaps enough to solidify it according to its composition. If sufficient time is provided during which the droplet is passing through the oxidizing zone outside of the flame envelope and before contact with the cooling surface, it may lose some or all of its sticky property and become a solid which will not adhere strongly to the cooling surface. The indication is that high intensity of heat absorption should be sacrificed to allow time for cooling the particles. Under such conditions furnace walls may become "self-cleaning" as was indicated in a report of the Special Research Committee on Furnace Performance Factors.[2] In Part 4

[2] Reported at A.S.M.E. Meeting, Chicago, June 1947.

of that report entitled "Comparison and Correlation of the Results of Furnace Heat Absorption Investigations," by A. R. Mumford and G. W. Bice, the effect of ash deposits on heat absorption is indicated. Fig. 2 (Fig. 5 of the report) shows the relation between a multiplying factor and the thickness of the ash deposit. Thus, for a deposit 1 in. thick the heat transmitted would be only 0.4 of that for a clean surface.

A new factor, the adjustable burner, has been introduced to aid in the control of superheat and has been applied to many boilers in the high-pressure high-temperature field where superheat control is of great importance. This burner is adjustable so that the flame may be directed up from the horizontal about 30 deg and down from the horizontal about the same amount. The same report showed that the furnace efficiency can be increased or decreased at will over a wide range by changing the firing direction. The effect on the temperature of the gases leaving the furnace was over 400 F so that superheat control was placed more completely in the hands of the operator over wide limits. In the case of this boiler, presented as an example of what the designer is doing to lessen the effect of accidental insulation of furnaces by ash deposits, a conservative design is shown to be at least partly self-cleaning with added control given the operator to offset any changes introduced by changes in fuels.

A continuation of the U. S. Bureau of Mines study on coal-ash slags was reported by W. T. Reid and P. Cohen in 1944 entitled "Factors Affecting the Thickness of Coal-Ash Slag on Furnace Wall Tubes."[3] In Fig. 3 (Fig. 1 of that report) the authors show their conception of the nature of ash deposits on furnace tubes. The rather high figure for the temperature of the outer surface of the tube may be questioned. Under similar conditions this author has measured temperatures of 590 to 625 F. A temperature of 700 to 750 F may exist before the ash starts to accumulate but would drop rapidly as the ash insulates the surface. Undoubtedly a sharp rise in temperature of the surface of the ash occurs even when the surface is first dusted. As the layer of ash increases in thickness its surface temperature will rise until the temperature of the critical viscosity is reached above which the ash becomes more and more fluid as the temperature rises until it flows as a liquid to the furnace bottom and is removed as a liquid. Obviously, the temperature of the outer surface of the tube is directly affected by the rate of heat transfer and when the designer keeps that rate down to a moderate figure the surface temperature will be lower. The sticky nature of a droplet of molten ash is retained only as long as it is prevented from cooling by being surrounded with hot gases or because the period between its escape from the flame and its impingement on water-cooled surfaces is too short. This time element is probably a factor of the ratio of the area of the flame and the area of the furnace-cooling surface. The designer has been successful in decreasing ash deposition on parts of the furnace envelope by replacing the large low-velocity burners with burners designed for higher velocity and for direct and positive mixing of the fuel gas and air.

[3] *Transactions* A.S.M.E., 1944, pp. 685–690.

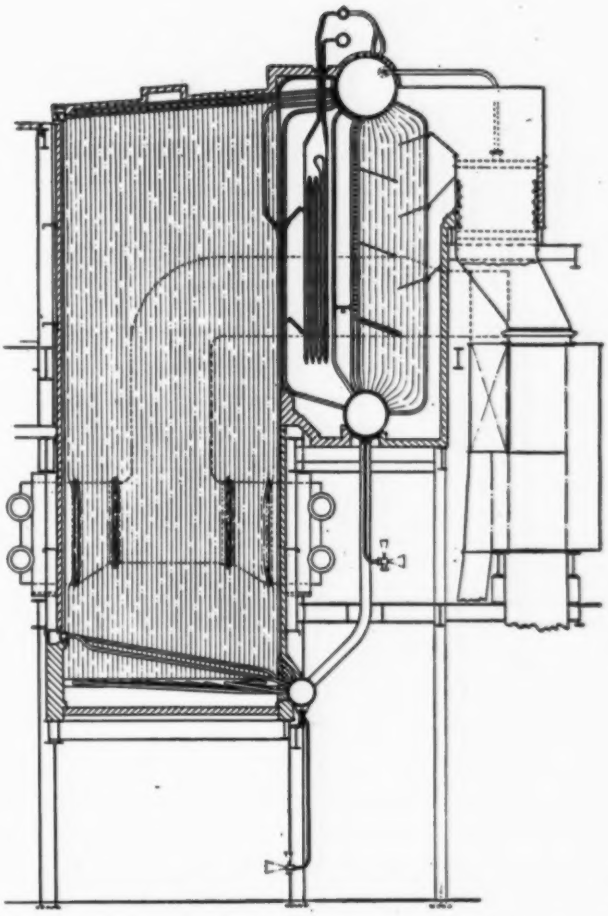

Fig. 5—Unit of 250,000 lb capacity for Bethlehem Steel Company at Johnstown

Fig. 4—Unit of 325,000 lb capacity for Bethlehem Steel Company at Sparrows Point

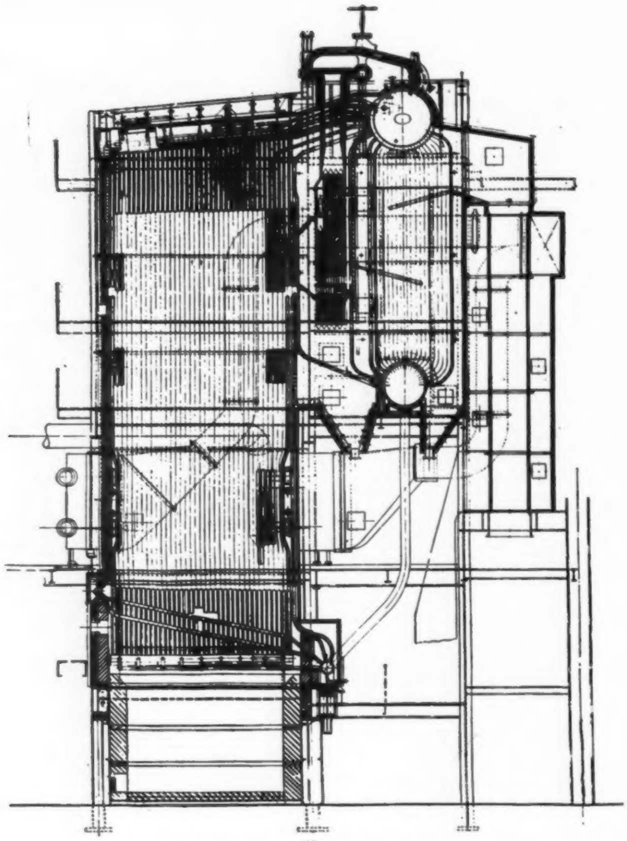

Fig. 6—Unit of 150,000 lb capacity for Republic Steel Company at Youngstown

The effect has been to bush out the flame, raise the local intensity of combustion, shorten the flame and allow more time for any molten particles to solidify before impinging on the heat-absorbing surfaces.

The designer's problem, when two or more fuels are used, is to maintain the right mixing and intensity of combustion with each alone or in combination so that combustion is completed and the flame temperature begins to fall a sufficient distance from cold surfaces so that adherence of slag is minimized. As has been indicated this problem is attacked by utilizing a combination of available factors. Generally, a conservative furnace design is a basic requirement. This maintains moderate rates of heat absorption and results in low tube surface temperatures. By burner design flame length is controlled to permit chilling of slag droplets. By burner position differences in fuel characteristics are compensated for to maintain superheat. By arranging the cooling surface so that the gas passages past the the first cooling surface are large, cooling is accomplished before the narrow passages, which might be bridged and clogged, are reached.

As the art develops the designer is continuously applying the findings of research and field performance to increase the availability and production rates to the maximum justified by economic conditions.

Some Late Designs of Steam Generators for the Steel Industry

Six units have been selected as examples of late designs of steam generators for the steel industry. The capacity of these units ranges from 325,000 lb of steam per hour for the largest to 75,000 lb steam per hour for the smallest. The largest is designed to generate its steam at 900 psig and 900 F while the smallest is generating its steam at 250 psig and 545 F. The primary fuel in each case is blast-furnace gas with supplementary fuels of coal, oil, coke-oven gas or coke breeze.

The design of a unit for the Bethlehem Steel Company at Sparrows Point is shown in Fig. 4. This unit is designed to produce 325,000 lb of steam per hour at 900 psig and 900 F total temperature. It will burn blast-furnace gas as the primary fuel with coke breeze on a traveling-grate stoker as a secondary fuel. The superheater is divided into a radiant section and the normal convective section. The radiant section is shielded from the furnace by a two-row screen of evaporating tubes and separated from the convective section by an additional two rows of evaporating tubes. The first screen is to chill any sticky slag in the gases so that superheater plugging will be minimized. To control the amount of superheat at several loads and with different proportions of the secondary fuel the convective section of the superheater may be bypassed by the dampers after the main boiler section. The gas flow can be divided so that the proper portion bypasses the convective superheater and the total temperature is held constant. The air heater is divided so that part of the air supply is heated for the blast-furnace gas and part is heated to a lower temperature for the coke breeze. An interconnection is provided so that the two sections of the air heater may operate as a unit or at intermediate mixtures up to the limit set by closing the damper on the interconnection. The stoker is well shielded by a long water-cooled rear arch so that the grate surface is protected at low rates of burning the secondary fuel. The high furnace provides a long travel for the stoker gases and sufficient travel for the combustion of the blast-furnace gas. The use of the bypass damper for super-

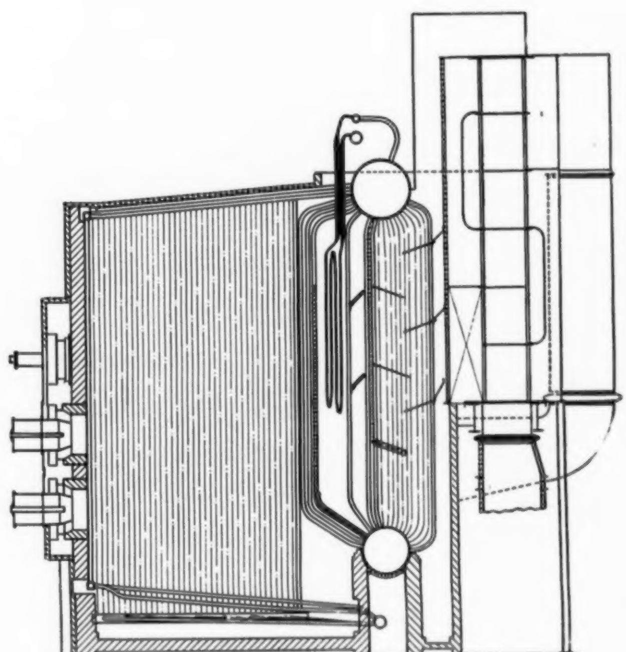

Fig. 7—Unit of 125,000 lb capacity for the Steel Company of Canada at Hamilton

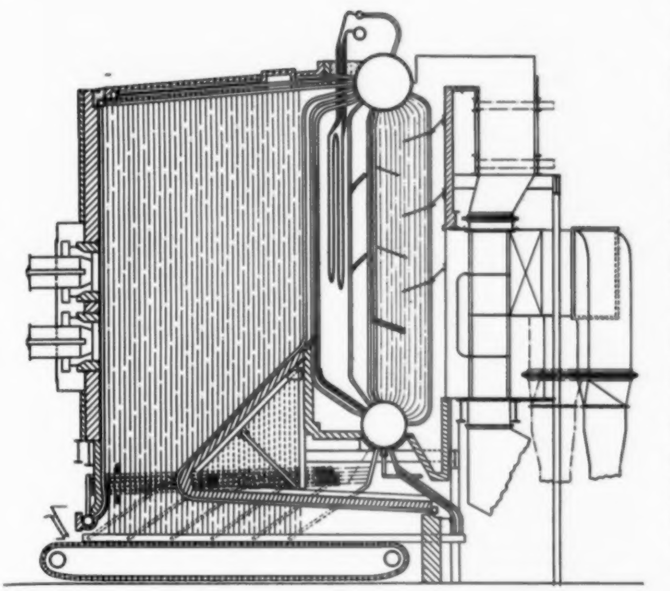

Fig. 8—Unit of 125,000 lb capacity for the Steel Company of Canada at Hamilton (with stoker)

heat control compensates for the designer's inability to move the stoker, with its comparatively low volume of combustion products, nearer to the superheater. Although not clearly shown in the figure three pre-mix steam atomizing oil burners are installed in each of the nine gas burners. When oil is not in use it is intended that some steam be passed through the burner for protection of the atomizing head. This unit is not yet in operation so field performance is not yet available.

Fig. 5 shows a unit being built for the Bethlehem Steel Company plant at Johnstown, Pa. It is designed for 250,000 lb per hr at 850 psig and 890 F total temperature. The unit will burn blast-furnace gas with oil as the secondary fuel. In this design the gas is fired from each corner and directed to form a tangent to a circle in the furnace. Corner firing is used extensively in other industries and has been particularly successful in maintaining low carbon losses in the flue dusts from pulverized coal firing and practically eliminating the necessity for distributing fuel and air to each corner in the same ratio. The intense turbulence and mixing action in the flame corrects for any differences in fuel-air ratio to each corner. In this installation the oil burners are installed between the two gas burners in each corner. Some of the wall tubes have been bent outward to provide, with a row of boiler tubes, a widely spaced slag screen in front of the convection superheater. A bypass around the superheater is arranged for control to compensate for the proportion of secondary fuel and its possible effect on furnace cleanliness.

Fig. 6 shows a unit for the Republic Steel Company at Youngstown. It is designed to produce 150,000 lb of steam per hour at 870 psig and 860 F total temperature. The primary fuel is blast-furnace gas, fired from the corners, with oil as secondary fuel. The design is quite similar to that shown in Fig. 5, except for the lower capacity and the somewhat lower temperature. The oil is fired from corner burners installed between the gas burners.

Fig. 7 shows a unit designed for the Steel Company of Canada. It is to have a capacity of 125,000 lb of steam per hour at about 450 psig and 750 F total temperature with blast-furnace gas. The secondary fuels are coke-oven gas and oil which are fired through the three upper burners while the four lower burners are used for the primary fuel. The upper position of the secondary fuel burners brings them nearer the superheater with less furnace cooling surface available to reduce the temperature of the products of combustion than exists for the blast-furnace gas.

The products of combustion for blast-furnace gas have almost twice the volume of those for secondary gaseous or liquid fuels. The effect of this difference in volumes on convective heat transfer in the superheater has already been mentioned and in this case the effect has been partly offset by the location of the burners. In this case the desire for a high temperature preheated air has resulted in placing the economizer after the preheater.

Fig. 8 shows another unit designed for the Steel Company of Canada to operate under the same capacity and conditions of pressure and temperature as that shown in Fig. 7. The secondary fuel in this unit, however, is coke breeze. Attention is called to the shielding of the stoker by the water-cooled arch and the exchange in the position of the economizer and air heater. This change indicates that the Steel Company of Canada considers coke breeze as the primary fuel in this case and as the stoker does not utilize as high a preheat in the air supply the advantage of position is given the economizer.

Fig. 9 shows the design of a unit for the Pittsburgh Coke and Chemical Company at Neville Island. This unit is operated at a capacity of 75,000 lb of steam per hour at 250 psig and 545 F total temperature. The secondary fuel is pulverized coal fired through the upper burners. Field operating experience with this unit has been very satisfactory particularly from the standpoint of availability. From the time of initial start until taken off for insurance and state inspection it was continuously on the line for the eleven elapsed months. During this period it generated 402 million pounds of steam from 100 per cent makeup feedwater. The average load for the entire period was 50,000 lb steam per hour. Automatic control maintains constant steam pressure with widely varying supply of primary fuel.

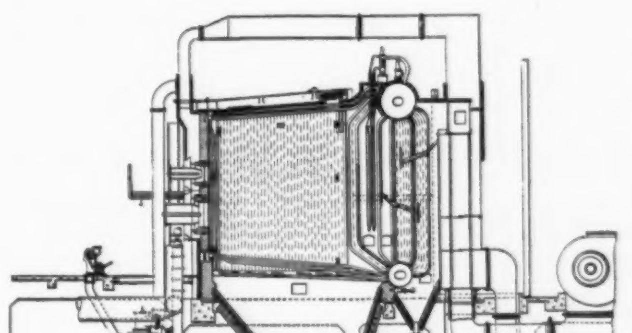

Fig. 9—Unit of 75,000 lb capacity for the Pittsburgh Coke and Chemical Company at Neville Island

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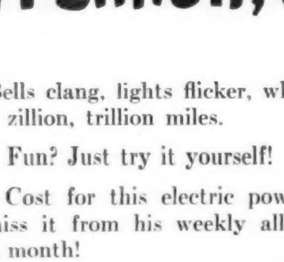

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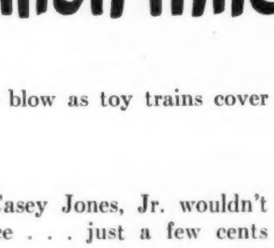

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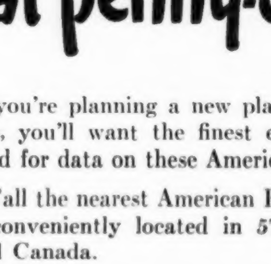

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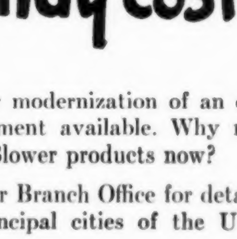

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Engineers Discuss How to Keep Power Boilers in Uninterrupted Service

High spots of a Panel Discussion held under the auspices of the New Jersey Division of the A.S.M.E. Metropolitan Section at Newark, N. J., on January 29. General topics covered were outages from external deposits, internal deposits, failure of auxiliaries and attitude of management.

THE panel was made up of four well-known power engineers, namely **C. H. Bean** of Calco Chemical Co., **D. C. Carmichael** of E. I. du Pont de Nemours & Co., **R. Gibson** of Public Service Electric & Gas Co., and **L. H. Zapfler** of the Standard Oil Co. of New Jersey. **Frank X. Gilg** of Babcock & Wilcox Co. acted as Chairman. The questions were arranged in four groups, that is, those dealing with external cleanliness of heating surfaces, with internal surfaces, with auxiliaries, and with management cooperation.

A daily check on gas temperature and draft loss was suggested as one of the best means of controlling the condition of gas passages. Various methods were discussed for cleaning these external surfaces with the unit in operation. When using steam soot blowers, it was urged that care be taken to see that they had been properly drained and that the source is dry steam. Where makeup must be kept low, air is to be preferred as the blowing medium.

With regard to hand lancing preference was shown for air or steam over water, although steam in such cases does present somewhat of a hazard to the operator. Granting that some hard scale responds best to water lancing, precautions must be taken not to use too large a jet of water, to keep the jet moving and to avoid impingement on refractories, headers and other parts that might be damaged. It was pointed out that in some cases of anthracite firing the semi-plastic character of the slag responds best to intermittent jets of water.

Boilers in many refineries burn waste products that cannot be marketed and a very pernicious scale results on the heating surfaces. In at least one refinery it is the practice to introduce sand into the furnace. This is carried along by the draft and produces an effective scouring action on the tubes to keep them clean of troublesome slag. In general, oil slag is soluble in water and can be washed off the tubes when the unit is out of service.

Experiences differed as to success with certain so-called "soot removers." In one plant employing straight-tube boilers burning oil, a soot-removal compound had been found effective in changing hard scale into soft scale that could be easily removed. The same compound, however, had no effect on scale in coal-fired boilers in this plant.

In burning oil, the degree of atomization and amount of excess air have bearing on slag formations on the heating surfaces. Moreover, there are some oils that contain salts and metal oxides which are released in burning and contribute to the formation of very hard slag that is most difficult to remove.

When burning small sizes of anthracite, Mr. Bean urged precautions against erosion of the tubes, by shielding any that may show signs of erosion, and keeping baffles tight. He strongly favored the reburning of cinders, despite the extra loading of the gases, as this makes for a finer ash. Moreover, such reburning makes for 3 or more per cent gain in overall efficiency.

Internal Deposits

Granting that one of the principal causes of forced boiler outage is tube rupture traceable to internal scale or corrosion, it was agreed that control through blowdown and proper feedwater treatment was the only preventative. This involves close checks on the feedwater for traces of oxygen and inspection of the deaerators. Inasmuch as the feeding of chemicals at the suction side of the pump may produce deposits on valves, etc., it was stated that, especially on high-pressure units, feeding directly into the drum is preferable.

One of the discussers, who is responsible for a number of both large and small plants, voiced the opinion that while most large high-pressure plants require expert individual attention as to feedwater treatment, it is usually satisfactory to employ certain boiler compounds in the smaller low-pressure boilers.

So-called "rope scale" and thinning of tube walls at the sides in the upper tubes of straight-tube sectional header boilers was cited as attributable to faulty circulation. That is, when the tube tends to run dry, or become steam-bound, dry caustic at the water level becomes excessive.

As to acid cleaning, it was agreed that some designs of boilers cannot be effectively cleaned mechanically and that acid cleaning is often cheaper from the standpoint of labor saving, but it should be done only when necessary and then employed with care under proper supervision. It appeared debatable as to whether it is necessary to replace all gaskets after acid cleaning, as experience seems to differ on this point.

Auxiliary Failures

In the category of outages due to auxiliary failures it was agreed that induced-draft fans head the list. Such troubles are usually due to blade failure, faulty bearing lubrication or coupling difficulties. Too high tip speed or abrasive material in the gases are usually responsible for blade erosion, although unbalance of the air streams with double-inlet fans may contribute to blade wear. Liners and resistant material for wheels have helped, but in applying liners extreme care must be exercised not to unbalance the rotor. Cinder collectors when placed ahead of the induced-draft fans have helped in many cases to keep down wear of the induced-draft fan blades.

Management Problems

It was noted as most important that those responsible for plant operation have a voice in the purchase of fuel. This is especially true at the present time when the quality of coal available may be uncertain.

As to the selection and training of maintenance men, practice differed. One discusser made it a practice to take such men from the factory on the recommendation of the foreman. Another had tried screening applicants but had not always found this effective. His experience indicated that the best way to keep such men contented is to rotate jobs.

Miscellaneous Questions

A question from the floor that elicited considerable discussion dealt with the delivery of coal through chutes. While steel is most commonly employed, a number favored chilled cast iron or nickel liners to minimize wear. Another had found glazed tile a most effective liner. Some plants employ vibrators to keep coal moving to the feeders, although these are generally noisy; but it was suggested that an oversize vibrator will tend to reduce the noise.

Considerable discussion centered around protective devices when firing with gas, to the end that the gas will be shut off if the flame is extinguished; but it was generally considered that no reliable gas shut-off valve for ignition failure, which would operate under all conditions, had yet been brought out.

Consumption of Bituminous Coal

According to Bituminous Coal Institute, the largest single market for bituminous is the railroads which account for approximately 20 per cent of the total output of the mines. About the same amount is taken by retail coal dealers, mainly for household and commercial uses. Next is the steel and coke plants which account for around 16 per cent of the annual output. The electric utilities normally consume about 14 per cent, although in 1947 with a consumption of over $89^1/_2$ million tons this figure rose to $14^1/_2$ per cent. Export tonnage amounted to nearly 8 per cent last year and the remainder was consumed by industry in general.

A SUB-SATURATION REHEAT CYCLE*

By W. E. CALDWELL

Mechanical Plant Engineer, Consolidated Edison Co. of New York

This treats briefly the conditions which necessitate reheating of steam in central stations and describes a method of reheating within the low-pressure turbine. It compares the suggested design with conventional practice by an elemental method which gives an approximation of the economic possibilities of the cycle.

HIGH pressure is recognized as a prerequisite to maximum economy in steam power production but the resulting moisture increase reduces efficiency in the wet stages and aggravates water cutting of the exhaust blades. Increasing initial steam temperature or reheating the steam during expansion is the usual compensating means employed for reducing the excess moisture which causes exhaust blade deterioration. The moisture limit is not merely a matter of thermal compromise but is a decisive factor in the life and reliability of the unit. About twelve per cent calculated moisture at condenser pressure is generally considered the economic limit but with this condition wet stage efficiency is low and maintenance is high. Numerous attempts have been made to solve this problem by drainage or internal modifications, with limited success, but it is well known that reducing the moisture will increase efficiency and reduce maintenance.

Conventional Reheating Practice

Reheat is more practical in reducing moisture in the exhaust stages than increasing initial temperature since more available heat per pound may be added within the temperature limits imposed by the physical properties of economical high-temperature alloys. Thus, 950 F at 400 psi will give about the same exhaust quality as 1300 F at 1500 psi. However, 1500 psi is too low for best economy and at present 950 F is about the upper limit of temperature for the time-tested lower cost alloys. Initial pressure of 2400 psi or more is justified for new plants, except for the associated moisture limitations which renders reheat a necessity for this pressure. Reheat temperatures of 950 F at 400 psi limits exhaust moisture to about 8 per cent at 1 in. exhaust pressure and represents the approximate economic limit for boiler gas steam reheat, due to the effect of increasing steam volume and pressure loss with diminishing pressure. Reheating to 360 F at 25 psi absolute pressure would give about the same exhaust condition, i.e., 8 per cent moisture at 1 in. exhaust pressure. For this pressure reheating at the boiler is not practical for the reasons mentioned, although live steam reheating at the turbine for medium capacity plants is attractive at this low pressure. A noteworthy example is found in the ore carrier *SS Venore* in which steam to the low-pressure turbine is reheated at 12.5 psi gage to 570 F reducing exhaust moisture to 2 per cent at 1.5 in. exhaust pressure. With these conditions turbine reliability should be high due to the elimination of water cutting of blades, shields, etc., common to high-moisture conditions.

A few steam-to-steam reheaters have been used in stationary plants at higher pressure. For large capacities the problems with high-pressure shell and tube reheaters outweigh the advantages. Boiler gas reheat is limited also by the physical properties of steam since the specific heat of steam diminishes with increasing temperature and declining pressure. The added amount of high level heat extracted from the boiler gases by reheat necessitates increasing gas temperatures in the tube banks, further aggravating the cleaning of gas passages in coal-burning plants.

The gain due to reheat takes place in the low-pressure turbine by an increase in available energy, a downward shift in the dew point and reduction in moisture in the subsequent stages. In addition to the gain in efficiency and available energy there is a reduction in the exit loss and loss to the condenser due to reduced steam flow. Partly offsetting the gains in the low-pressure turbine there is an efficiency loss in the high-pressure turbine by the use of reheat as a result of the reduction in flow volume through the high-pressure unit. There is also a cycle loss due to extraction of reheated steam by the intermediate pressure heaters. With reheat it is usually desirable to compound the turbine, which adds an extra bearing and two shaft seals with the additional steam leakage to be disposed of. And, finally, the major obstacle which handicaps conventional reheat, from the operator's viewpoint, is the operating complexities associated with it.

Thermal Advantage of Reheat

The high-pressure end of the turbine down to the dew point is, strictly speaking, a gas turbine. Since the gain due to reheat takes place in the low-pressure stages which ordinarily are below the dew point, this region warrants basic analytical study. For this purpose a 35,000 kw Rateau turbine of 1500 rpm, 25 cycles has been chosen as test information and dimensions on it are available, together with a twenty-year life history of blades. It may be taken for illustrative purposes to represent the exhaust end of a 60,000-kw high-pressure condensing tubine for 2400 psi initial pressure.

With initial conditions of 185 psi gage at 500 F and 1 in. abs. exhaust pressure this 35,000-kw unit requires about 12 lb of steam per kilowatt-hour. The water rate improves 1 per cent for each 11 deg F increase in steam temperature, which represents the addition of 6 Btu per lb of steam in the superheater. The resulting gain is produced by an increase in theoretical cycle efficiency

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* From a paper at the A.S.M.E. Annual Meeting in Atlantic City, N. J., December 1–5, 1947. For a discussion of this paper see the report of this meeting in COMBUSTION for December 1947.

and moisture reduction in the stages below the dew point which occur with the above initial conditions at about 40 psi gage. For moisture reduction the heat for dehydration may be added anywhere between the throttle and dew point with equal effect, or below the dew point, provided means for transferring the heat does not increase pressure loss in the main flow circuit.

From this it follows that within appropriate limits the thermal cost of the additional power produced by the evaporation of moisture in the turbine and the increase in available energy is $6 \times 12 \times 100 = 7200$ Btu per kwhr. Since the throttle heat rate of the conventional cycle for the steam conditions mentioned is about 12,000 Btu per kwhr, the thermal advantage of reheat is obvious. In the conventional reheat application the full amount of this gain cannot be realized due to losses incident to the cycle, together with temperature limitations, etc. Neglecting pressure loss, additional shaft leakage, etc., and with a boiler efficiency of 87 per cent the fuel input for boiler gas reheat is $7200/0.87 = 8300$ Btu per kwhr of reheat increment. In a steam-to-steam reheater the heat rate per reheat increment kilowatt-hour is somewhat higher due to other losses.

Sub-Saturation Reheating

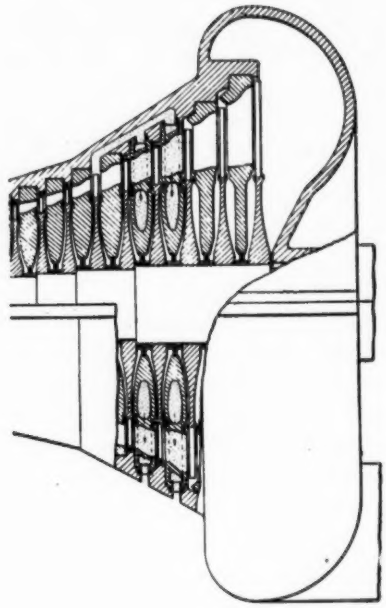
Since the moisture conditions which necessitate reheat ordinarily occur below the 100 psi stage in the turbine it affords an opportunity to reheat with bleed steam in combination with hollow stationary blades or nozzle partitions. The surfaces are adequate and the required temperature differences are obtainable with moderate pressure differences.

The illustration represents a low-pressure turbine with passages for reheating the bleed steam indicated. Steam bled from higher stages enters the top of the diaphragm passage, flows through the hollow blades to the center segment, then into the lower half of the diaphragm and on down through the lower blades to the bottom drains. The condensate would be discharged at the temperature corresponding to the heating steam pressure to re-enter the feed cycle. No external piping or apparatus is necessary other than condensate drain connections.

For simplicity of illustration only two stages of reheat are shown, while in actual practice reheating the last three stages would be justified. The number of stages to be heated may be determined on the basis of economics with initial steam conditions, turbine efficiency and costs as major influences. Efficiency would be increased by the addition of heating stages up stream until the dew point is reached.

Hollow stationary blades are now used in some turbines to improve strength, performance and methods of fabrication. The blades are made of plate and formed into the required blade section after which they are welded into diaphragm or half-ring assemblies for insertion in the turbine casing. Introduction of low-pressure heating steam into the hollow stationary blades is a simple engineering problem.

In the use of bleed steam reheating within the turbine it is not the intent to superheat the steam because it is only necessary to evaporate excess moisture as it is formed. Below the dew point moisture increases about 2 per cent per stage and the evaporative capacity of the heated nozzles is adequate for this duty. This arrangement is, in effect, a multi-stage steam reheater within the wet region of the turbine casing.



Elemental cross-section of self-contained reheating turbine with single-stage two-row nozzle reheat

With boiler gas reheat the heat transfer coefficient in the reheater is about 10 with transfer from flue gas to gas (superheated steam). In the steam-to-steam reheater of the shell-and-tube type the heat transfer coefficient is about 80 with change in state (condensation) on the heating side and gas heating (superheated steam) on the other side. With evaporative reheating below the dew point the coefficient will be much higher due to the more favorable transfer conditions which prevail, i.e., condensation within the blades and evaporation on the outer surfaces.

From a review of available information it appears that a coefficient of heat transfer of 1100 may be expected with mild steel partitions 0.15 in. thick, or about 1600 with copper. These values are for clean blades. It follows that with mild steel nozzles the moisture produced per stage may be evaporated with a mean temperature difference of 80 deg F just below the dew point and 40 deg F or less for the lower stages. After the surface moisture is evaporated the coefficient when superheating would drop to about 70.

It would be the general objective to limit the moisture content in the steam to the supersaturation zone or not more than about 4 per cent, since under these conditions the stage efficiencies would be approximately that of the superheat region.

Bleed steam provides an economical source for reheating and contributes more to the economy as the initial pressure is increased. With 2400 psi 950 F steam chosen for the throttle condition the first extraction point for steam reheating would be at about 100 psi pressure, while the lowest would be about 8 psi absolute and the mean about 30 psi absolute. The expansion of the bleed steam from throttle to the 30-psi extraction point will produce 1 kwhr for 11 lb of steam flow before condensing in the reheating nozzles and provide additional power as follows:

Power produced by 11 lb of reheating steam expanding from 2400 to 30 psi absolute....................	1.0 kwhr
By resulting evaporative reheat $\frac{11 \times 945}{(7200 \div 0.8)}$.......	1.15 kwhr
(0.8 is the approximate moisture component of the superheat correction)	
Energy produced by 11 lb of steam expanding from pressure of 2400 to 30 psi and adding 10,400 Btu to steam in the wet stages.........................	2.15 kwhr
Fuel input in 11 lb of steam with 87 per cent boiler efficiency and 440 F feed temperature $\frac{11 \times (1428 - 420)}{0.87}$ =.........................	12,750 Btu

Heat rate of increment power added by dehydration of wet stages with bleed steam $\frac{12,750}{2.15}$ = approximately 6000 Btu per kwhr of reheat increment

When evaporating 12 per cent moisture in the wet stages from the 75 per cent of throttle steam flowing and with a 10,000 Btu per kwhr basic heat rate the approximate overall rate is as follows:

$$
\begin{aligned}
0.12 \times 0.75 &= 0.09 \text{ throttle flow fraction} \\
0.09 \times 6000 &= 540 \text{ reheat component} \\
0.91 \times 10{,}000 &= \underline{9100} \text{ basic component} \\
\text{Combined heat rate} &= 9640 \text{ Btu per kwhr}
\end{aligned}
$$

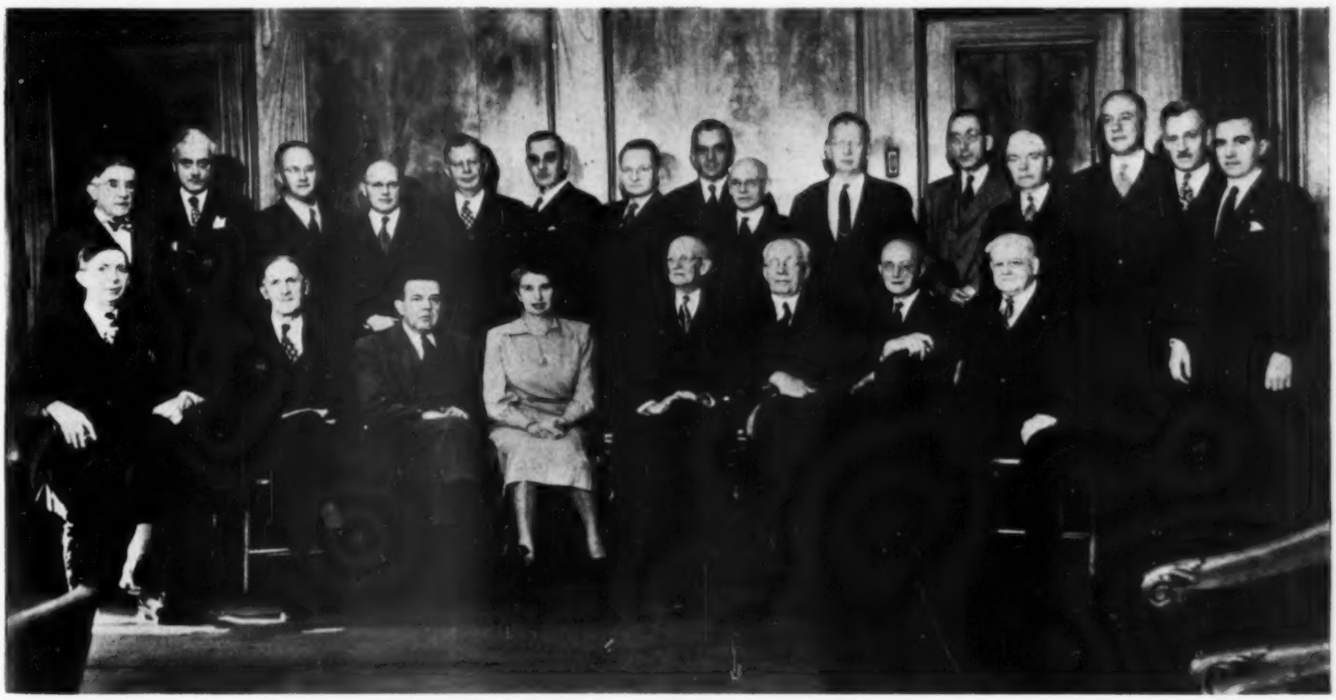
Ignoring the consequences of excessive moisture the expansion of the 11 lb of steam from 30 psi down to 1 in. absolute would yield 0.6 kwhr instead of 1.15 kwhr resulting from its use for reheating.

This short cut approximation was chosen as a simple means of presenting the basic fundamentals of the cycle and is not intended as a precise indication of expected performance. Diminishing returns toward the last stage have been ignored due to the compensating influence of the increasing output by the bleed steam used for reheating. Also, the loss in energy dissipated by the last wheel in churning water probably exceeds the value usually assigned to it as indicated by the relative rates of blade erosion. More test information is needed to determine accurately the performance of the suggested cycle and this paper merely serves as an introduction to the subject. From the limited information available, however, certain deductions may be drawn.

The ratio of moisture evaporated to total flow determines the approximate overall heat rate and within appropriate limits the economy would be but slightly affected by a reduction in initial steam temperature. This characteristic eliminates the need for wide range superheat regulation, together with associated control apparatus.

Evaporative reheating releases the choice of initial steam pressure from the limitation imposed by initial temperature, and exhaust moisture conditions. It offers more effective moisture control than by increasing initial steam temperature where costs, operating conditions and metallurgical problems are becoming intolerable. Thus, it permits building a simple two-bearing condensing turbine in a single unit for any initial pressure up to the critical with an initial temperature of 950 F or less with overall economy excelling that of turbines now available.

The need for super alloys for abnormally high temperature and for resisting water cutting is obviated since initial steam temperatures may be reduced while maintaining a dry exhaust. As this method of reheating requires no regulation, operating simplicity is assured, and compared with present practice it offers lower production costs with less capital investment.



The Boiler Code Committee of The American Society of Mechanical Engineers recently completed 37 years of service in the interest of public safety. The Code has been adopted as law by 28 states and 9 of the provinces of Canada, some of the Committee's rules having legal standing.

Members of the committee shown here are: seated left to right—A. C. Weigel, C. W. Obert, W. P. Gerhart, Martha Jurist, D. S. Jacobus, Honorary Chairman, H. B. Oatly, Chairman, C. A. Adams, V. M. Frost; standing—C. O. Myers, P. R. Cassidy, F. S. G. Williams, J. W. Turner, A. J. Ely, D. L. Royer, H. C. Boardman, A. L. Penniman, Jr., R. E. Cecil, W. F. Hess, Walter Samans, S. K. Varnes, D. B. Rossheim, E. C. Korten, (alternate for W. D. Halsey) T. H. Currier, Secretary. Other members of he committee are H. E. Aldrich, F. W. Davis and James Partington.

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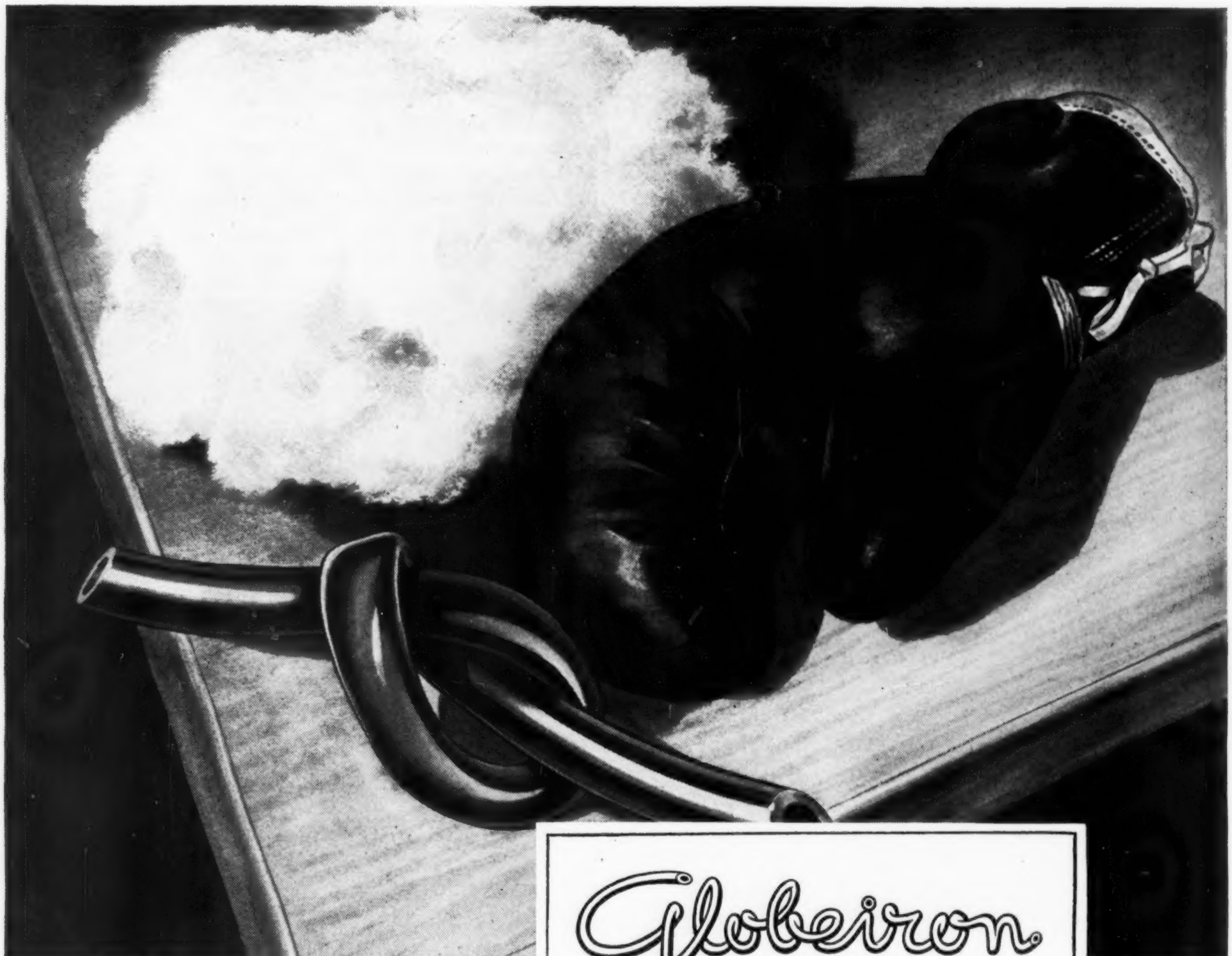

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Synthetic Fuels Plants Recommended

EARLIEST possible construction of initial commercial plants for the production of oil and gasoline from coal and oil shales was proposed by Secretary of the Interior Krug in his annual report to Congress on progress of the synthetic liquid fuels research and development program of the Bureau of Mines, which was authorized by Congress several years ago.

With demand for petroleum and its products at unprecedented heights and still rising, and reserve productive capacity exhausted, he recommended construction of at least three synthetic fuels plants—one using oil shale and the others using coal and different extraction processes as models. He added, that during the coming year, with the assistance of industrial leaders interested in liquid fuels and the technical advice of the Bureau of Mines, specific recommendations would be made for the erection of the necessary plants and the founding of an American synthetic fuel industry.

James Boyd, Bureau of Mines Director, and administratively in charge of activities under the Synthetic Liquid Fuels Act of 1944, reported to Secretary Krug that all research laboratories and the oil-shale demonstration plant contemplated in the original Act are in full operation. A coal hydrogenation demonstration plant will be completed this year.

The report to Congress shows the progress in synthetic liquid fuels research and development made by the Bureau of Mines in the face of recurrent shortages and rising costs during and since the war. In his letter of transmittal, Secretary Krug pointed out that to complete the objectives set forth by Congress in 1944, it is essential that this program be extended beyond April 1949, the expiration date of the present authorization. It also is essential that additional funds be provided soon to permit construction of a gas synthesis demonstration plant and prevent curtailments and delays in research activities, he added. Legislation for this purpose is now before Congress.

The Secretary emphasized that the magnitude of a synthetic fuels industry adequate to compensate for any future deficiency in domestic petroleum requires that a start be made now, using data already available from research and demonstration plant work. Preliminary estimates indicate that production of two million barrels of synthetic oil a day—less than 40 per cent of our current daily consumption—would require the use of 16 million tons of steel and the expenditure of about nine billion dollars, he said. Men would have to be trained for mining, plant operation and all other functions of this large industry. Such an operation would be ten times the size of the synthetic rubber program completed during the last war.

Reviewing 1947 research and development progress of the Bureau of Mines in the field of synthetic fuels, a program undertaken at the direction of Congress to insure the Nation's economic and military security, the Secretary reported as follows.

Oil-Shale Demonstration Work

At Rifle, Colo., the Bureau's oil-shale demonstration plant produced its first crude shale oil in May when the retorts were placed in operation. Since then, operating under a predetermined schedule of experimental runs, the plant has been producing at a rate of about 50 barrels a day. Concurrently, three additional types of retorting units are being built and will be tested.

The present estimated cost of producing crude shale oil on a large scale is, roughly, \$2 to \$2.50 per barrel. This oil would not compare favorably in quality with oil produced from natural petroleum now selling at those prices but if the recent trend toward price increases continues, it will be easily competitive.

Pending completion of a refinery, now under construction, the shale oil is being used in laboratory engine tests and refining studies. That unneeded for these purposes has been burned successfully as fuel oil in combustion tests conducted in the plant's boiler unit. By relatively simple refining, crude shale oil yields No. 5 or 6 residual fuel oil suitable for use in ships or utility plants. However, further refining improvements will be required to produce the lighter distillate, diesel fuel and gasoline on a commercial basis. To speed refining studies, a cooperative test program will be undertaken with a number of oil companies.

Coal-to-Oil Demonstration Work

At Louisiana, Mo., a demonstration plant to produce about 200 barrels of gasoline a day by the hydrogenation of coal is under construction on the site of a Government-owned wartime synthetic ammonia plant. To be completed this year, this plant will employ operating pressures ranging from 4,000 to 10,000 psi.

The demonstration plant will use from 100 to 200 tons of coal or lignite daily. Western coals will be used in initial operations because some of them are exceptionally well suited to hydrogenation processing. Other coals, including eastern, midwestern and southern, will be tested after the usual operating difficulties encountered in "breaking in" a new plant are ironed out.

Under present conditions and with Bureau-developed process improvements, including heat efficiencies more than 20 per cent better than the Germans were able to attain, it is estimated that a high-grade motor gasoline or aviation gasoline can be produced commercially from coal for about 14 cents a gallon, some 5 to 7 cents more per gallon than the current cost of gasoline from petroleum. This estimate includes an allowance for plant amortization but otherwise includes an estimate for only production costs. On the other hand, no credit has been taken for by-products

which may reduce the cost of the product in some plants by 3 to 5 cents a gallon.

If funds are available, construction will begin next summer on a gas synthesis (Fischer-Tropsch) demonstration plant to produce motor gasoline and diesel fuel from coal. This plant also will be erected at Louisiana, Mo., and will make about 50 to 80 barrels of oil daily.

Employing product cost-reduction features developed in Bureau laboratories and pilot plants at Bruceton, Pa., and Morgantown, W. Va., this plant will have coal-gasification units of a new design. It also will incorporate a newly developed converter unit which can be built to produce 500 or more barrels daily as compared to a capacity of 18 barrels a day for the German converters. A good grade of motor gasoline and an excellent diesel fuel can be produced through this process at costs which probably approximate those of the coal hydrogenation process. Although estimates have been made, they require verification in actual operation of a demonstration plant.

Oil-Shale Research

At Laramie, Wyo., a new oil-shale research and development laboratory building has been completed, providing the space and facilities needed for determining the fundamental chemical, physical and engineering facts of oil-shale processing. Engine tests were started on shale gasoline and diesel fuel to determine their characteristics for use in internal-combustion engines.

Coal-to-Oil Research

At Morgantown, W. Va., site of the synthesis gas laboratory and pilot plant unit, encouraging progress was made on processes for cheap production of the carbon monoxide and hydrogen required in synthetic fuels manufacture. In the Bureau's laboratories, three processes were under study for making this synthesis gas, the major cost factor in the finished product and the most important single research problem: (1) gasification of coal in place underground; (2) gasification of pulverized coal entrained in superheated steam containing oxygen; (3) gasification of powdered coal with oxygen and steam in a vortex reactor.

Underground coal gasification, offering the initial advantage of saving mining costs, perhaps is the most interesting. A field test conducted at Gorgas, Ala., with the cooperation of the Alabama Power Company yielded promising results. It showed that combustion can be maintained in unmined coal, that the coal can be gasified and consumed completely, and that gases produced can be used for generating power. If the operation can be conducted with oxygen and under pressure, very high temperatures and a suitable synthesis gas should be obtained. Many problems remain to be solved, however. Further work is in progress in the laboratory, and detailed plans are being made for additional field tests.

A laboratory-scale apparatus for producing synthesis gas from pulverized coal is in operation at Morgantown, and a larger pilot plant is being built. In this process, too, results promise material cost reductions for synthesis gas, now made

commercially in this country only in the standard water-gas sets. New methods for purifying synthesis gas also are under study there.

At Pittsburgh, Pa., an experimental vortex reactor for gasification of powdered coal with oxygen and steam has been built and is under test at the Bureau's experiment station. Heat loss from the unit, which has a design capacity of about 100 lb of coal per hour, is estimated to be less than 5 per cent. If successful, it should be adaptable to almost any type of coal.

At Bruceton, Pa., structures to house the main coal-to-oil laboratories and pilot plants were substantially completed in 1947 and Bureau personnel took possession, moving from temporary quarters at Pittsburgh as space became available. Meanwhile, research continued on the hydrogenation and gas synthesis methods of converting coal to oil, and process improvements offered promise of further material cost reductions.

Hydrogenation is the only large-scale synthetic process now well adapted to the production of aviation gasoline from coal, yielding a base stock for 100-octane gasoline with good rich-mixture performance. It does not produce a diesel fuel of as high a quality as the gas synthesis process, but may offer a good method of obtaining fuel oil.

In the coal hydrogenation field, high yields of distillate were obtained in experiments conducted on steam stripping of heavy oil slurry. This eliminates the unsatisfactory centrifuging and coking operations employed in German plants to purge ash and other unreacted solids. Effective new catalysts were discovered which reduce the amount of asphalt present in the primary product and largely or wholly eliminate the use of the strategic and critical tin previously required. Equipment was installed for the separation and identification of synthetic fuel components, some of which may offer sources of special fuels and chemical by-products and thus reduce processing costs. Bench-scale units were designed and fabricated for hydrogenating coal in a dry or powder state, a discovery which constitutes a radical departure from European practice.

In the gas synthesis field, production rates several times those in German plants were achieved in a redesigned and rebuilt pilot plant employing an internally cooled converter developed by the Bureau. In addition, bench-scale experiments were made on other processes including the liquid-phase catalyst suspension, hot gas recycle and fluidized fixed bed. Work on the latter process is particularly important in the design of projected commercial plants for the production of synthetic liquid fuels from natural gas.

At Peoria, Ill., the Department of Agriculture has placed in operation a small semi-works plant to determine the manufacturing steps and costs for producing alcohol and other liquid fuels from agricultural residues. The process, developed by the Bureau of Agricultural and Industrial Chemistry, consists of converting the pentosan fraction of the agricultural residues to pentose sugars and subsequently the cellulose fraction to dextrose which are then converted to the liquid fuels butanol, isopropanol, acetone, ethanol or furfural

Program of Midwest Power Conference

A preliminary program of papers to be presented at the Tenth Annual Midwest Power Conference has just been made available and will be further amplified as pending arrangements take definite form. So far, the program lists 22 sessions and over 50 papers. The Conference, as previously announced in these columns, will be held at the Sheraton Hotel, 505 N. Michigan Ave., Chicago, April 7–9, *inclusive.*

Following an address of welcome by **Prof. D. D. Ewing** at the opening session on Wednesday morning, "Estimates of Future Electric Power Needs" will be presented by **F. R. Benedict** of Westinghouse Electric Corp.; "Flood Control and Power in the Southwest" will be discussed by **Edwin Vennard** of the Middle West Service Co.; and **John M. Drabelle** of the Iowa Electric Light & Power Co. will talk on "The Trek of Industry Westward."

At noon there will be a joint luncheon with the A.S.M.E. Chicago Section, but the speaker has not yet been announced.

There will be five technical sessions on Wednesday afternoon—one on Central Station Practice; one on Developments in Heating; one on Diesel Power; another on Electrical Measurements; and the fifth on Power Plant Equipment and Appraisal. Papers for the Central Station Session are still pending. At the Heating Session, "Design Procedures in Panel Heating" will be covered by **Prof. F. W. Hutchinson** of the University of California and a "Comparison of Panel and Convection Heating in a Research Residence," by **S. Konzo** and **R. W. Roose** of the University of Illinois. The diesel engine papers are "Combustion in Diesel Engines," by **Otto Uyehara** and **P. S. Myers** of the University of Wisconsin, and "A Test Cell for Measuring Engine Noise," by **W. P. Green** of Illinois Institute of Technology. Among the papers on electrical measurements will be "Measurement of Power and Power Factor in Industrial Plants," by **Erwin Boland** of General Electric Co.; "D. C. High Power Distribution Systems," by **William Deans** of I.T.E. Circuit-Breaker Co.; and "Electrical Measurement of Nonelectrical Quantities," by **E. S. Lee** of General Electric Co. At the Power Plant Equipment session **A. P. Darlington** of American Blower Corp. will discuss the "Selection of Mechanical Draft Fans"; **H. F. Lowe,** consulting engineer, will talk on "Steam Power Plant Appraisal"; and **R. J. Martin** will deal with "Condensers, Their Use and Application in Water-Shortage Areas."

On Thursday morning four sessions will deal with Feedwater Treatment, Excitation Systems, Hydro Power and Locomotive Power Units. The respective papers listed are: "Causes and Prevention of Condensate-Return-Line Corrosion," by **R. T. Hanlon** of National Aluminate Corp.; "The Practical Approach to Modern Boiler Water Treatment," by **R. C. Ulmer** of E. F. Drew & Co.; "Excitation Requirements and Control of Reactive Power," by **W. A. Lewis** of Illinois Institute of Technology; *"Rotating Regulator Exciters,"* by **C. Lynn** of Westinghouse Electric Corp.; "Japanese Electric Power System," by **E. J. Burger** of the Ohio Public Service Co.; "Sediment Transportation in Streams in Relation to Power Plant Operation," by **M. C. Boyer;** and "The Gas Turbine Locomotive," by **P. R. Broadley** of the *Locomotive Development Committee.*

A joint luncheon with the A.I.E.E. Chicago Section will follow at which the speaker will be **A. C. Monteith,** of Westinghouse Electric Corp., whose topic will be "Opportunities in the Power Field."

Rural Electrification, Power Plant Operator Training, General Power Systems and Industrial Power Plants will be the general subjects covered in the four Thursday afternoon sessions. The first of these will include papers on "Rural Electrification from the Power Company Viewpoint," by **Grover C. Neff,** president of the Wisconsin Power & Light Co.; "European vs. American Distribution Systems," by **K. R. Brown;** and "Application of Oil Reclosers on Distribution Systems," by **R. O. Askey** and **C. V. Miller.** The speakers on "Power Plant Operator Training" will be **Kenneth R. Hodges, Julius Barbour, Garrett Burgess** and **Stephen C. Casteel.**

At the third session **Walker L. Cisler** of Detroit Edison Co. will talk on "The Foreign Power Situation," and **E. W. Kimbark** of Northwestern University on "Power System Stability." Under Industrial Power Plants there will be three papers, namely, "Furnace Design Methods, With or Without Water Walls," by **Ollison Craig** of Riley Stoker Corp.; "Application of Heat Balance Analysis to Industrial Plants," by **H. C. Carroll** of Commercial Testing and Engineering Co.; and "Experiences with a Multiple-Fuel-Fired Water-Tube Boiler," by **R. F. Hollis** of Alton Box Board Co.

The "All Engineers Dinner" is scheduled *for Thursday evening.*

On Friday morning there will be two papers on the heat pump—one entitled "Heat Source Possibilities of the Earth," by **C. H. Randolph** and **O. O. Wagley,** and the other on "An Investigation of the Heat Pump for the Chicago Area," by **M. S. Oldacre** of the Utilities Research Commission. For the second session on feedwater treatment there is scheduled a paper on "Use of High Alkalinity and Organic Materials for Sludge Removal in High-Pressure Boilers," by **S. K. Adkins** of the Omaha Public Power District, and "Recent Developments in Boiler Water Research," by **Prof. F. G. Straub.**

The session on Power and Control will have three papers, one on "Circuit Principles of Industrial Electronic Control," by **Walter Richter** of Allis-Chalmers, another on "Rectifier Power Supplies from D. C. Systems," by **C. R. Marcum** of Westinghouse, and a third on "Electronically-Con-

trolled Variable-Speed Drives," the author to be announced later. Under Fuels and Combustion **W. C. Schroeder** of the Bureau of Mines will discuss "Underground Coal Gasification Experiments," and **A. D. Singh** will talk on "Possibilities of Coal Processing in Power Production."

At a joint luncheon with the Western Society of Engineers, Friday noon, the speaker will be **Charles E. Friley,** president of Iowa State College.

This will be followed by a general session devoted to "The Engineer in Civic Affairs," at which the principal speakers will be **H. T. Heald,** president of Illinois Institute of Technology and **S. M. Dean** of the Detroit Edison Co.

Three other sessions on Friday afternoon will be devoted to Supervisory Control and Telemetering, The Gas Turbine, and Conductors. For these the following papers are listed: "Telemetering of Power, Reactive Power and Similar Quantities," by **Nathan Cohn;** "Telemetering Channels," by **R. J. Donaldson;** "Supervisory Control," by **A. P. Peterson;** "Progress Report on the Coal-Burning Gas Turbine," by **J. I. Yellott** and **C. F. Kottcamp;** "Why So Many Gas Turbine Cycles," by **L. N. Rowley** and **B. G. A. Skrotski;** "Operation and Test Experience with an Experimental 2000-Hp Gas Turbine," by **T. J. Putz;** "Development of Requirements for Copper Wire Connections," by **F. E. Sanford;** and "Synthetic Rubbers and Resin Insulation for Wires and Cables," by **J. T. Blake.**

The Conference, as for several years past, will be under the direction of **Stanton E. Winston** of the Illinois Institute of Technology.

New Books

Instrument and Control Manual for Operating Engineers

By Eugene W. F. Feller

As the title implies, this is a practical book prepared primarily for engineers in industrial plants concerned with instrumentation and automatic control for both power plant and process operations. The range of subjects covered includes liquid-level instruments; pressure and temperature elements; motor-operated pressure- and temperature-operated valves; hygrostats and psychrometers; control mechanisms and systems; emergency instruments; feedwater controls; traps and condensate systems; valves; and mechanical governors. The text is well illustrated and the general treatment comprises basic explanations followed by descriptions of commercial instruments and their applications.

There are 426 pages, $5^1/_2 \times 8$ in. and the price is $6.

Combustion Engineering

This is a first edition. Edited by Otto de Lorenzi, director of education, Combustion Engineering Company, and contributed to by thirty members of that company's technical staff, the book deals with the various methods and equipment used for fuel burning, steam generation and heat recovery.

The preface defines the subject of *combustion engineering* as "the science of burning fuel to liberate heat and make it available to perform useful work," and describes the *combustion engineer* as "one who is skilled in the art of burning fuel and who is frequently a designer of fuel burning, steam generating and related equipment." These definitions serve as a guide to the scope and purpose of the work.

Separate chapters are devoted to each type of stoker, pulverized fuel burning equipment, burners for liquid and gaseous fuels, and furnaces for wood refuse and bagasse. All types of stationary boilers are covered in one chapter of more than forty pages, with separate chapters on marine boilers, forced circulation boilers, electric boilers, superheaters and desuperheaters, and heat recovery equipment. A full chapter is devoted to the A.S.M.E. Boiler Construction Code.

Other subjects to which complete chapters are devoted are the origin and production of coal; fuels for steaming purposes; fluid cycles; steam purification; feedwater; performance calculations; drafts, fans and chimneys; selection of equipment; testing of steam generating units; and operation and maintenance of equipment.

Combustion Engineering is probably the most comprehensive technical book ever published by an equipment manufacturer. Its thirty-odd chapters and appendix run to well over a thousand pages and include more than 400 illustrations and about 80 tables. The Appendix includes complete steam tables, and a Mollier Diagram is tipped in to the back cover. The 54-page chapter entitled "Fuels for Steam Purposes," while devoted mainly to coals, covers virtually all commercially used fuels and contains a section on combustion calculations. The information on coals in this chapter is limited to domestic deposits, but the Appendix contains descriptive information and, in many cases, typical analyses, of coals throughout the world.

This book is designed for the use of both engineering students and practicing engineers. It is priced at $7.50, but will be made available to students in recognized engineering schools, through their instructors, at a nominal price.

Size $6^1/_4 \times 9^1/_4$ in., bound in heavy buckram. Published by Combustion Engineering Company, Inc., 200 Madison Avenue, New York 16, N. Y.

A.S.M.E. Spring Meeting in New Orleans

The 1947 Spring Meeting of the American Society of Mechanical Engineers will be held March 1 to 4 at New Orleans, La. Some eight technical sessions are scheduled for the presentation of around twenty-five papers on gas turbines, metals engineering, power, materials handling, heat transfer, fuels, processing and management.

The power papers will have a local slant inasmuch as one will deal with "Design and Operational Features of the Industrial Canal Steam-Electric Station" and the other will discuss "Carry-over Improvement on a High-Pressure Boiler at the Baytown Refinery." Those on gas turbines will include "The Gas Turbine as a Stationary Prime Mover," "Gas Turbine Power Plants for Operation by Low Cost Fuel," "The Performance of Commercial Gas Turbines" and a survey on "How New Gas Turbines Fit into Tomorrow's Power Pattern." Other papers of particular interest to power men are "Utilizing Bagasse as Fuel" and "Conversion of the Big Inch and Little Inch Pipe Lines from Oil to Gas Transmission."

Inspection trips will include a visit to the new steam-electric power plant of the New Orleans Public Service, Inc., located on the Industrial Canal.

Stone & Webster Acquires Badger

According to an announcement on Jan. 15, Stone & Webster, Inc., of Boston has acquired E. B. Badger & Sons Co. for the purpose of expanding the engineering and construction activities in the process and industrial fields of its subsidiary, Stone & Webster Engineering Corp. The acquired company is an old and well-known construction firm originated over 100 yr ago in Boston where its head offices are maintained. For the present both organizations will continue to operate as individual entities.

Largest Heat-Pump Installation in U. S.

Although some large heat-pump installations have been operating abroad and a number of smaller ones in this country, what is purported to be the largest in the United States was described by J. D. Kroeker and R. C. Chewning in a paper before the A.S.H.V.E. early this month. This describes the installation in the 12-story Equitable Building in Portland, Ore., which serves the dual purpose of heating the building in winter and cooling it in summer. Well water is employed as the source of heat.

Obituaries

Walter H. Wood, service engineer with Combustion Engineering Co., Inc., died suddenly of a heart attack at Piqua, O. on February 5.

Born at Fayetteville, Ark., October 7, 1875, Mr. Wood received his technical education at the University of Arkansas, and following graduation became associated with his brother, Albert C. Wood, consulting engineer of Philadelphia, for a period of 14 yr. Two years were spent as combustion engineer with the American Writing Paper Company and a year in charge of stationary power plants of the B. & O. Railroad. In March 1917 he joined Combustion Engineering Company where he organized and became head of its test department. He remained in that work until 1931 when he was transferred to service engineering, where his extensive field work brought him in contact with the operating personnel of many installations in the United States, as well as South America and Canada.

It may be recalled that he was the author of numerous papers and articles dealing with testing and with operation of traveling-grate stokers, subjects upon which he was regarded as an authority. Surviving are his wife and one son.

Dr. August C. Klein, vice president and engineering manager of Stone & Webster Engineering Corporation, died on February 2 of coronary thrombosis while on vacation in Jamaica, the British West Indies. He was 60 yr. old. During the war he was project engineer of his company's work for the Manhattan Atomic Bomb Project and was identified with the atomic pile at the Argonne Forest Laboratory of the University of Chicago. Surviving are his widow, Mrs. Maree S. Klein, and four sons.

Clifford B. Le Page, assistant secretary of the A.S.M.E., died suddenly on January 15 at Hartford, Conn., after attending a meeting of the American Standards Association. A graduate of Stevens Institute of Technology with the class of 1902, Mr. Le Page taught at that school for a number of years and became associated with the A.S.M.E. in 1918 as secretary of its standing committees on research, standardization and power test codes. He was also assistant director of the Secretariat for Prime Movers of the International Electrotechnical Commission.

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